(12) UK Patent Application (19) GB (11) 2 361 211 (13) A

(43) Date of A Publication 17.10.2001

(21) Application No 0108633.9

(22) Date of Filing 05.04.2001

(30) Priority Data
(31) 09546247 (32) 10.04.2000 (33) US

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(51) INT CL[7]
B41M 3/14

(52) UK CL (Edition S)
B6C CSD
B6F FAX F201 F234 F263

(56) Documents Cited
None

(58) Field of Search
UK CL (Edition S) B6C CSD CST , B6F FAX
INT CL[7] B41M 3/14
ONLINE DATABASES: EPODOC, JAPIO, WPI

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(54) Abstract Title
High reliability forensic marking system

(57) A forensic marking system (10) and method for identifying the printing device (50) on which a medium (16) was printed. Encoded forensic markings (20) which identify the device (50) but are of low perceptibility to the human eye are superimposed on the printed image (14). The markings (20) have a color, size, density, and repetition pattern that only minimally affect print quality while providing highly accurate identification of the printing device (50), even if the printed medium (16) contains high-density image (14) content. The markings are generated from data representing the printer in an information marker and superimposing encoded information marker checksum data and information marker so as to create output data corresponding to the ferensically marked image, which is then printed using a predetermined colour difficult to detect by the human eye, but readily detectable by electronic scanning so as to identify the printer.

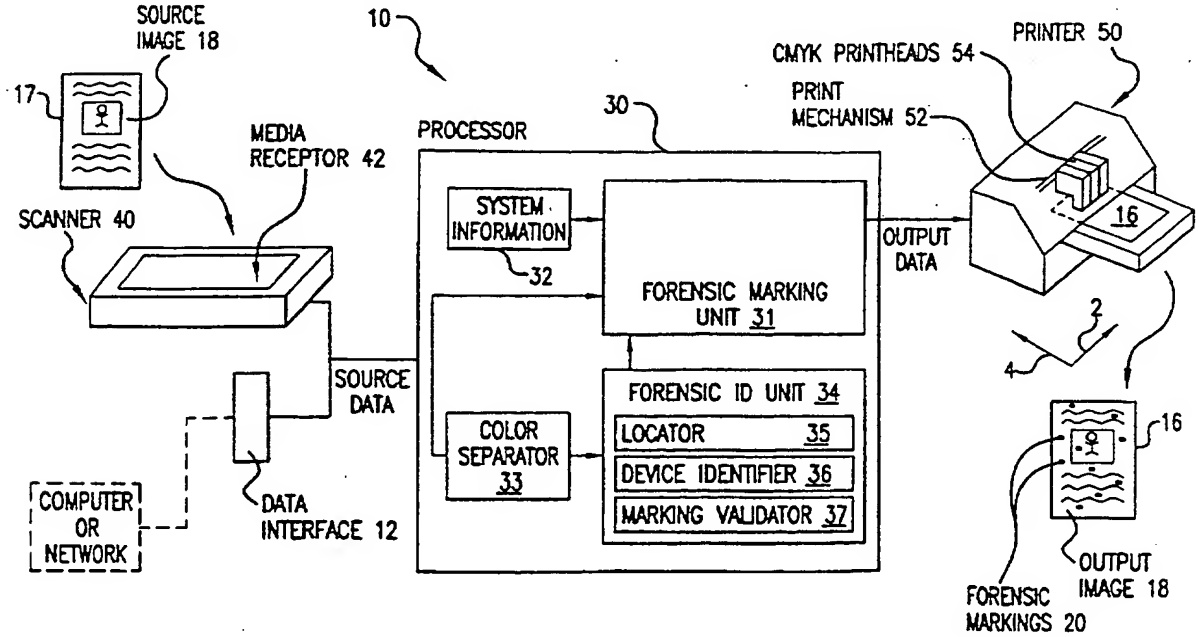

FIG. 1

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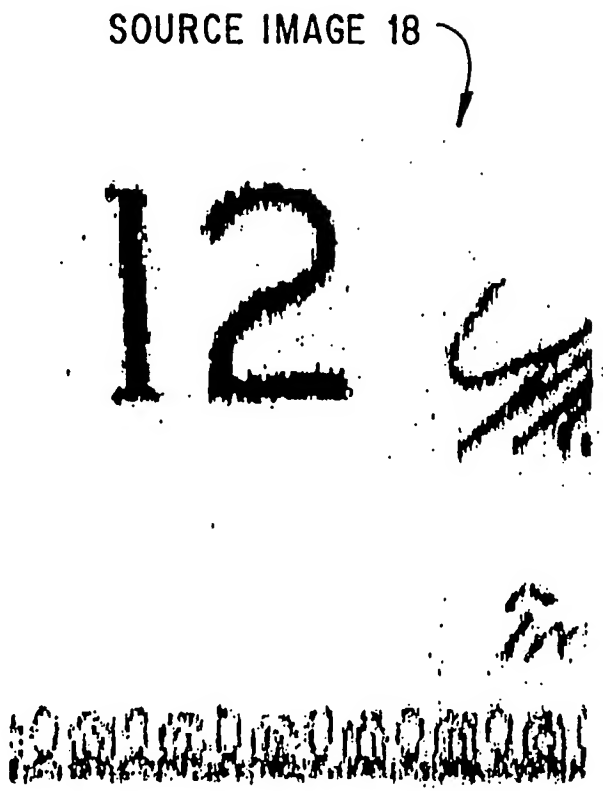

FIG. 2A

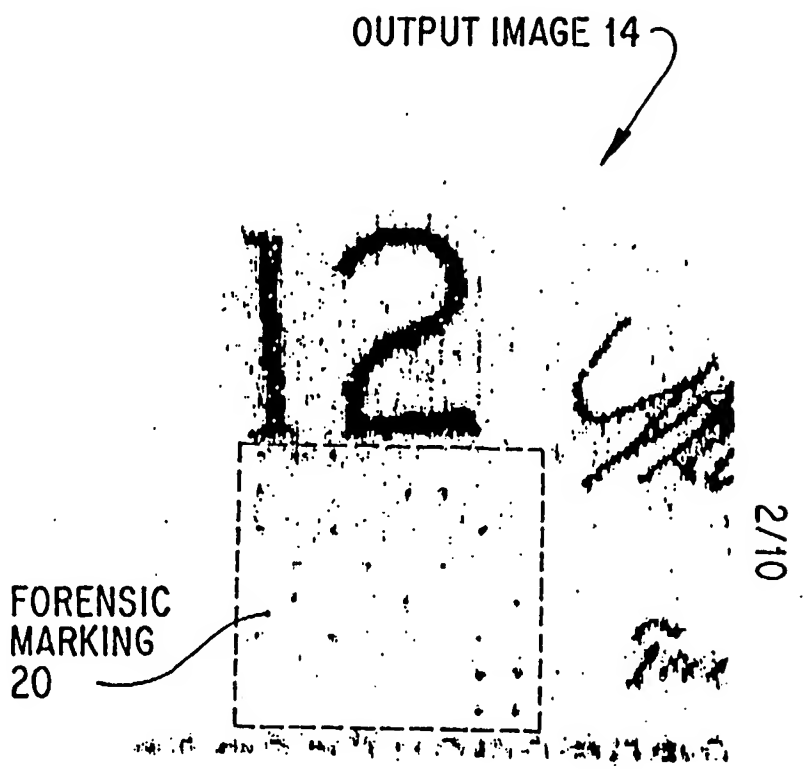

FIG. 2B

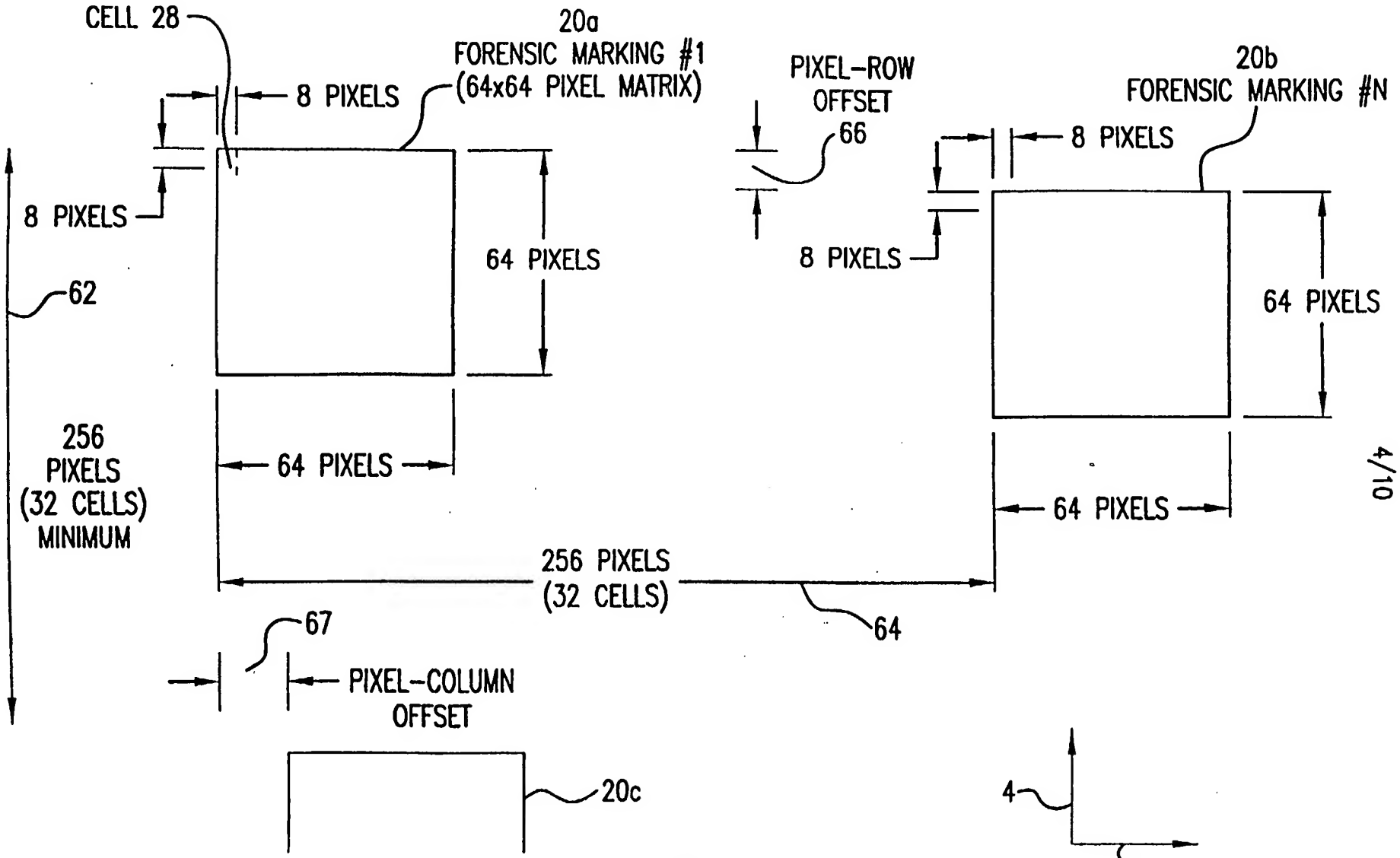
CELL 28
20a
FORENSIC MARKING #1
(64x64 PIXEL MATRIX)
8 PIXELS
8 PIXELS
64 PIXELS
62
256
PIXELS
(32 CELLS)
MINIMUM
64 PIXELS
256 PIXELS
(32 CELLS)
64
67
PIXEL-COLUMN
OFFSET
20c
PIXEL-ROW
OFFSET
66
8 PIXELS
20b
FORENSIC MARKING #N
8 PIXELS
64 PIXELS
64 PIXELS
4
2

FIG.4

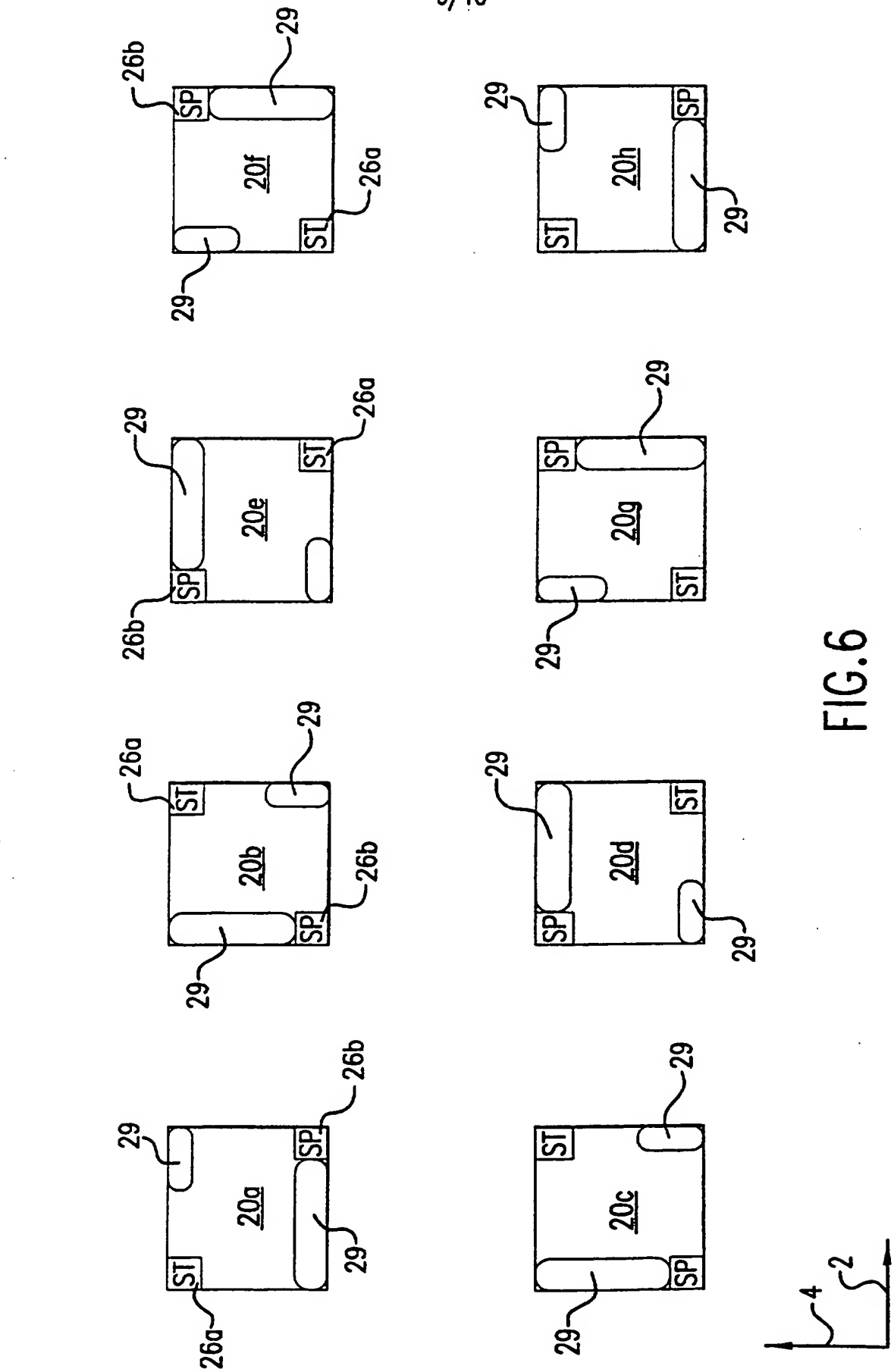

FIG.6

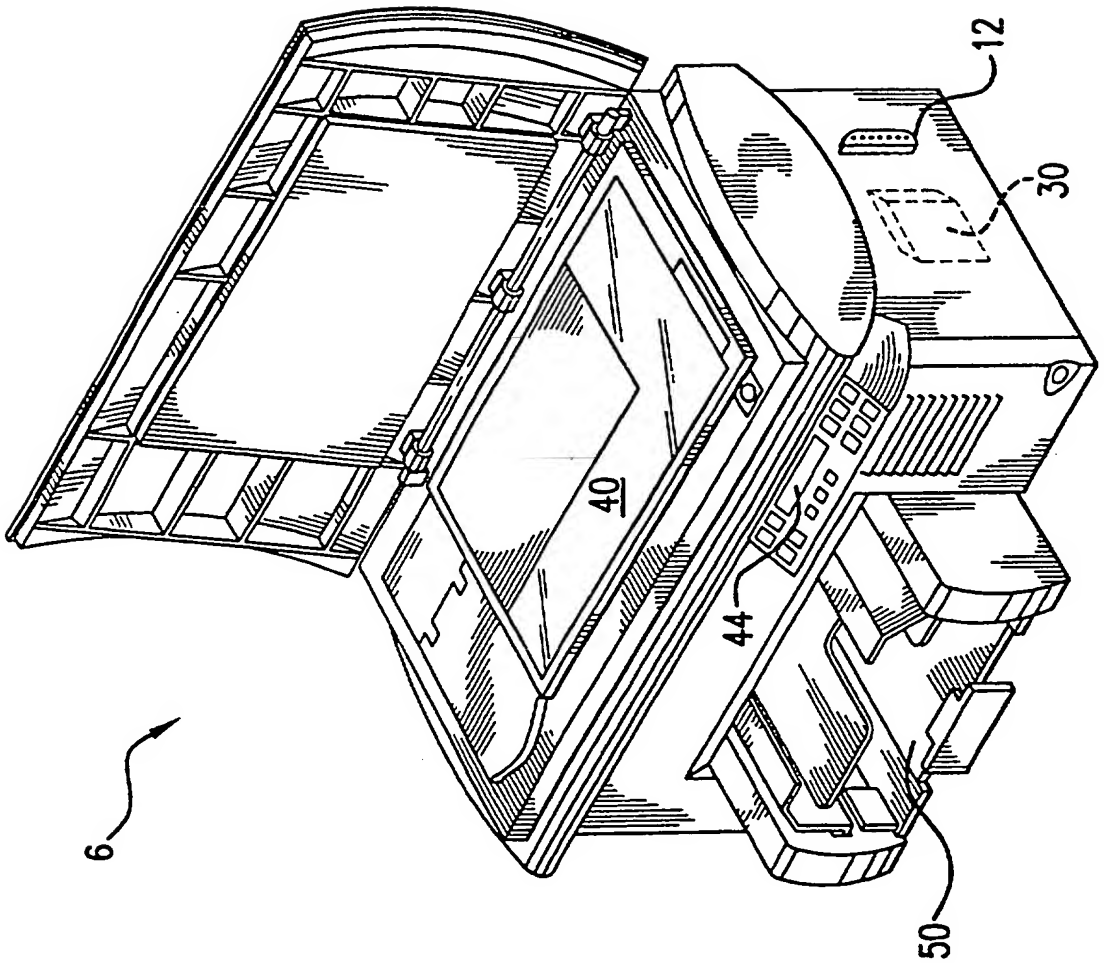

FIG.8

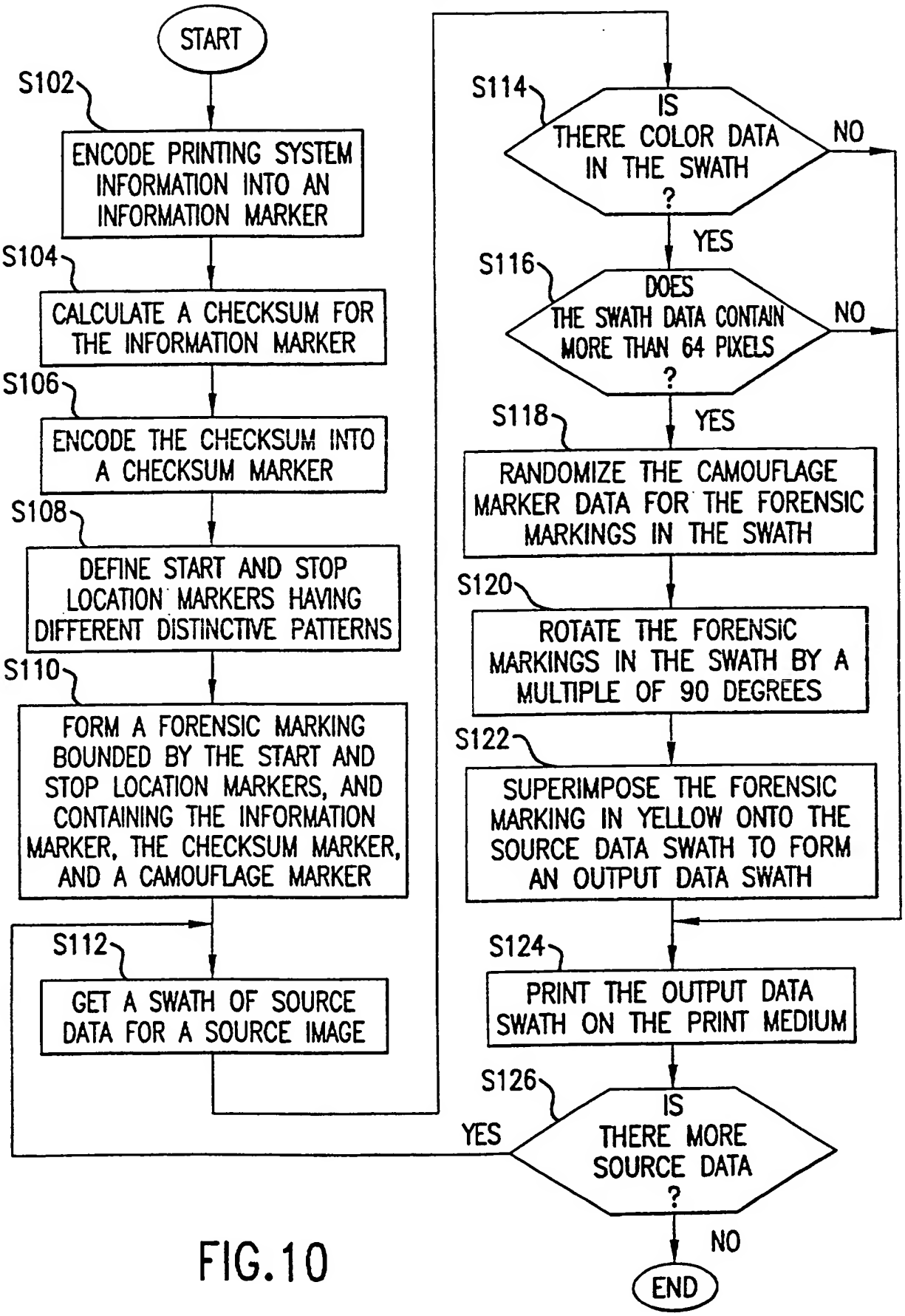
START
S102
ENCODE PRINTING SYSTEM INFORMATION INTO AN INFORMATION MARKER
S104
CALCULATE A CHECKSUM FOR THE INFORMATION MARKER
S106
ENCODE THE CHECKSUM INTO A CHECKSUM MARKER
S108
DEFINE START AND STOP LOCATION MARKERS HAVING DIFFERENT DISTINCTIVE PATTERNS
S110
FORM A FORENSIC MARKING BOUNDED BY THE START AND STOP LOCATION MARKERS, AND CONTAINING THE INFORMATION MARKER, THE CHECKSUM MARKER, AND A CAMOUFLAGE MARKER
S112
GET A SWATH OF SOURCE DATA FOR A SOURCE IMAGE
S114
IS THERE COLOR DATA IN THE SWATH ?
NO
YES
S116
DOES THE SWATH DATA CONTAIN MORE THAN 64 PIXELS ?
NO
YES
S118
RANDOMIZE THE CAMOUFLAGE MARKER DATA FOR THE FORENSIC MARKINGS IN THE SWATH
S120
ROTATE THE FORENSIC MARKINGS IN THE SWATH BY A MULTIPLE OF 90 DEGREES
S122
SUPERIMPOSE THE FORENSIC MARKING IN YELLOW ONTO THE SOURCE DATA SWATH TO FORM AN OUTPUT DATA SWATH
S124
PRINT THE OUTPUT DATA SWATH ON THE PRINT MEDIUM
S126
IS THERE MORE SOURCE DATA ?
YES
NO
END

FIG.10

information can also be transmitted to and received from an attached computer. In some instances, a modem is provided to allow scanned text and other images to be transmitted via facsimile over telephone lines to a remote location.

At the same time as the color image quality obtainable from scanner-printer configurations has improved, the cost of these devices has decreased making them more widely available and more readily accessible. This increased copy quality and device accessibility has raised concerns about the proliferation of illegal counterfeiting of documents such as paper currency, negotiable instruments, identification papers, and the like. A related concern is the undesired copying of proprietary or confidential business documents intended for only limited distribution.

Two general classes of solutions to these problems have been developed. The first type, "active" counterfeit prevention systems, attempt to recognize during the scanning process documents which should not be copied, and if such a copy-prohibited document is detected, prevent the printing of a copy. Such systems require advance knowledge of the image characteristics of the types of documents that are not to be copied, and must reliably detect these documents when copying of them is attempted. As a result, they tend to be expensive, in part because accurate determination of prohibited versus acceptable originals is difficult, and also because the system must be programmed to recognize each type of document intended to be protected.

The second general class of systems are "passive" marking systems. Such systems tend to be less complex in part because they do not attempt to prevent the copying of certain documents, but rather imprint all copies they produce with additional forensic information. Frequently this forensic information will identify the manufacturer,

Consequently, there is still a need for a passive marking system which minimizes the impact of forensic markings on print quality by forensically marking the printed medium with a small amount of imperceptible information overlaid on the image content, while ensuring that the passive marking system that produced the printed medium can accurately be identified from the forensic markings.

Summary of the Invention

In a preferred embodiment, the present invention provides a forensic marking system that unobtrusively marks printed media with encoded system information which subsequently allows the system on which the media were printed to be identified from the media with a high degree of accuracy, even where the markings are superimposed on other image content on the media. Such a marking system serves as a deterrent to counterfeiting of valuable documents by allowing the counterfeited materials to be traced back to their source.

The preferred forensic marking system has a processor which superimposes onto source data representing the image to be printed at least one forensic marking. The source data may be provided to the marking system in electronic form from a data interface coupled to the processor. In some embodiments, the forensic marking system may also include a scanner coupled to the processor for acquiring the electronic source data by optically scanning a source image contained on a printed medium. The forensic marking contains an information marker which identifies the system, and an checksum marker which validates the integrity of the information marker. The system also includes a printer coupled to the processor which receives the combined source data and forensic

column intervals. In addition, adjacent forensic markings are offset from each other by a one pixel-row.

The present invention may also be implemented as a method for printing a forensically marked image with a printer. The forensic marking is printed using a predetermined color such as yellow which is difficult to detect by the human eye, but readily detectable by electronic scanning so as to identify the system. Such a method encodes system information identifying the printer into an information marker, calculates a checksum for the information marker, encodes the checksum into a checksum marker, superimposes at least one encoded forensic marking containing the information marker and the checksum marker onto source data so as to create forensically marked output data, and prints that output data on a print medium. In some embodiments, the method also adds to each forensic marking at least one location marker which identifies the location and rotation of the corresponding marking on the print medium. The forensic marking may also include at least one camouflage marker containing a randomized data pattern to reduce the visibility of the forensic markings replicated on the printed medium. In cases where the printer prints a swath of the image on the medium at a time, the invention may also embodied in a method which obtains a swath of image data for the source image, and if more than a threshold amount of color data exists in the swath of image data, superimposes onto the image data a swath of at least one forensic marking having an encoded pattern of image pixels in graphical form. Then the method prints the image data on the medium to produce a forensically marked image. This method may be repeated until all the swaths of image data are printed. Typically the method will be performed by the processor of the printing system.

In still another embodiment, the information marker of the forensic marking can alternatively or additionally indicate whether copying of the forensically marked image is allowable or prohibited. If the printing system determines that the source image contains a forensic marking with an information marker indicating that the source image should not be copied, the printer will be disabled and a printed copy will not be produced.

Other aspects and advantages of the present invention will become apparent from the following detailed description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

Brief Description of the Drawings

FIG. 1 is a schematic representation of a passive marking printing system embodying the present invention.

FIG. 2A is an example source image associated with the passive marking printing system of FIG. 1.

FIG. 2B is an example output image produced by the passive marking printing system of FIG. 1 for the example source image of FIG. 2A.

FIG. 3 is a schematic representation of a forensic marking produced by the printing system of FIG. 1.

FIG. 4 is a schematic representation of the replication of forensic markings produced by the printing system of FIG. 1 on a printed output medium indicating the placement of multiple markings on the medium.

FIG. 5 is an enlarged example forensic marking produced by the passive marking printing system of FIG. 1.

A preferred embodiment of the printing system 10 includes a processor 30 for superimposing onto source data at least one forensic marking 20 having an encoded pattern of image pixels in graphical form so as to create output data corresponding to the forensically marked output image 14. The source data is preferentially provided to the processor 30 either in electronic form via a data interface 12, or from an optical scanner 40 electrically connected to the processor 20 which acquires the source data from a source image 18. The construction and operation of optical scanners is well known to those skilled in the art, and is described in further detail in articles in the *Hewlett-Packard Journal* ["Designing a Scanner with Color Vision" (August 1993, p.52), and "Design of a 600-Pixel-per-Inch, 30-Bit Color Scanner" (February 1997, p. 54)], which are hereby incorporated by reference in their entirety. The preferred embodiment also includes a printer 50 electrically coupled to the processor 30 for printing the output data so as to produce the forensically marked image 14. As will be discussed subsequently in further detail, the forensic markings 20 are printed at certain locations, intervals, and orientations on the forensically marked image 14 using a color to which the human eye has a low visual response, but one which is readily detectable by electronic optical scanning. A preferred embodiment of the printer 50 is a color inkjet printer which includes a print mechanism 52 which uses cyan, magenta, yellow, and black colorant print cartridges 54 in order to print color images 14. Typically a color inkjet printer 50 prints a horizontal portion, or swath, of an image 14 on the print medium 16 as the print cartridges 54 are scanned across the surface of the medium 16 in a scan direction 2. The construction and operation of color inkjet printers is well known to those skilled in the art, and is described in further detail in various articles in several editions of the *Hewlett-*

While the single drop per cell embodiment just described is preferred, the present invention also contemplates depositing additional drops per cell, in order to allow more complex encoding patterns at the expense of increased print density.

Considering now the content of the forensic markings 20 in further detail, each forensic marking 20 contains a plurality of markers. Each forensic marking 20 includes an information marker 22 indicative of the system 10, and a checksum marker 24 indicative of the information marker 22. Each forensic marking 20 also includes at least one location marker 26 which locates and orients the marking 20 on the printed medium 16 as will be discussed in further detail subsequently. Each marker 22,24,26 spans one or more cells 28. The cells 28 of a marker may all be contiguous, or a marker may be split into two or more sections of cells 28. Each marker 22,24,26 is printed on the medium 16 in graphical form as an encoded cell pattern.

In the preferred embodiment, the information marker 22 contains sufficient information to identify the system 10 which printed the output medium with a high degree of certainty. Identification information can include any of the manufacturer, model number, serial number, and purchaser or owner of the printing system 10. This information is encoded in the marker 22 and printed using a particular binary code. The information marker 22 of the preferred embodiment includes a machine type identifier section 22a to encode the type of system 10, and a machine serial number identifier section 22b to encode the serial number of the system 10. High accuracy identification of the system 10 is important in cases where a prohibited source image such as currency was illegally copied, in order not to misidentify an alleged counterfeiter. The checksum marker 24 contributes to high accuracy identification by providing redundancy to ensure

patterns and one blank cell. By positioning two different location markers at opposite corners, and by ensuring that the four cells in each of the other two corners of the forensic marking 20 do not contain either the start marker 26a or stop marker 26b patterns, the forensic marking 20 can be reliably identified by electronic scanning regardless of the orientation of the source image 18 on the media receptor 42 of the scanner 40.

Considering now the placement of the forensic markings 20 on the forensically marked image 14, and as best understood with reference to the exemplary illustration of FIG. 4, in the preferred embodiment the markings 20 (such as markings 20a, 20b, and 20c), are replicated at certain locations, intervals, and orientations so as to provide a plurality both to provide redundancy so as to improve the accuracy of printing system 10 determination in the event some of the markings 20 are corrupted, as well as to ensure that the markings 20 cannot easily be cut out of a printed medium 16 before making a subsequent copy of it so as to defeat the forensic marking scheme. As will be discussed subsequently in greater detail, superimposing portions of the forensic markings 20 in regions of the output image 14 which also contain portions of the source image 18 further reduces the ability to cut out forensic markings 20 without also cutting out a corresponding portion of the source image 18. The replicated markings 20a,20b,20c are located at predetermined pixel-row intervals 62 and pixel-column intervals 64 relative to each other. In the preferred embodiment and as depicted in FIG. 4, the pixel-column interval 64 is 256 pixels, which is equivalent to 32 cell-column intervals. The pixel-row interval 62 is 256 pixels (32 cell-rows) minimum; in the preferred embodiment any individual pixel-row interval 62 may be increased as required to avoid splitting forensic

embodiments they may be printed with random data so as to make at least some of the forensic markings 20a-h different from others. In addition, while the exemplary illustrations of FIGS. 3 and 6 show a forensic marking 20 having two camouflage markers 29 located as shown, different numbers and locations of camouflage markers 29 within the forensic marking 20 is contemplated by the present invention.

Considering now the superimposing of the forensic marking 20 on the source image 18 in further detail, and with reference to the exemplary marking patterns of FIGS. 7A, 7B, and 7C, there are illustrated three examples of a four-pixel portion 70a-c of a forensic marking cell 28. The upper left pixel 62a of each cell portion 70a-c denotes the pixel of the cell 28 into which yellow colorant can be deposited to form the forensic marking 20, while the remaining pixels 62b-d will not receive any colorant for the forensic marking 20. All four pixels of cell portions 70a-c may be imprinted using the appropriate combination of cyan, magenta, yellow, and black colorants as required to render the source image 18. Cell portion 70a illustrates the case where the source image is blank in this portion. In this case, if the cell 28 is to be forensically marked, two drops of yellow colorant (indicated by the two rectangular markings) are deposited into pixel 62a. Cell portion 70b illustrates the case where the source image contains cyan and magenta data in this portion. In this case, if the cell 28 is to be forensically marked, two drops of yellow colorant (indicated by the two rectangular markings) are deposited into pixel 62a along with the magenta and cyan drops (indicated by circular markings). Cell portion 70c illustrates the case where the source image contains yellow data in this portion. In this situation, no yellow forensic marking colorant will be added to that which will be deposited for the source image.

embodied in a printer 8 which does not contain a scanner 40 but which does incorporate the processor 30, printer 50, and data interface 12. In operation, the printer 8 receives in electronic form the source image 18 to be printed from a device, typically a computer, connected to the data interface 12. In yet another alternative embodiment of the printing system 10, both the scanner 40 and the printer 50 are separately packaged and connected to a computer (not shown) having the processor 30. While the just-described configurations are illustrative of the breadth of the present invention, they are not intended to limit its scope to just these configurations.

The present invention may also be implemented as a novel method for printing a forensically marked image on a print medium 16 using a color swath printer. The forensic markings 20 added to the source image 18 to be printed consists of a graphical pixel pattern formed by an arrangement of markers, each of which markers has a graphical pixel pattern. As best understood with reference to FIG. 10, the method begins with encoding S102 printing system information sufficient to identify the system 10 on which the print medium 16 was printed, described previously herein, into an information marker 22. Next, a checksum for the information marker 22 is calculated S104. The checksum preferably is the total number of cells 28 printed to encode the system information. For example, the information marker 22 of the forensic marking 20 of FIG. 3 has 32 possible cells that could be printed to represent the system information, so the checksum would have a value in the range of zero to thirty-two. According to the method, this checksum value is then itself encoded S106 into a checksum marker 24. Start 26a and stop 26b location markers which serve to delimit the area encompassed by forensic markings 20 are defined S108; each of these markers has a different distinctive

be printed ("No" branch of S126), the method ends. In some embodiments, the forensic markings 20 for certain swaths may be further modified before printing. At S118, randomized data may be inserted into the camouflage marker 29 to reduce the perceivability of the markings 20. Alternatively or in addition, each of the forensic markings 20 in the swath may be rotated S122 by a multiple of ninety degrees, which can also reduce the perceivability of the markings 20.

The processor 30, as best understood with reference to FIG. 1, includes modules which may be implemented in hardware, firmware, software, or any combination thereof to perform the above-described method. A forensic marking unit 31 receives the system information 32 and source data, and performs the calculation, encoding, randomization, rotation, and superimposition required to form the forensic markings 20 in the output data sent to the printer 50.

Other aspects of the present invention involve examination of the forensic markings 20 printed on a particular source medium 17. As best understood with reference to FIG. 1, the present invention may be implemented as a system 10 for identifying the printing device on which a particular medium 17 was printed via forensic markings 20 imprinted on the medium 17. The medium 17 is placed on the media receptor 42 and scanned by the scanner 40 to acquire multicolor electronic source data corresponding to the source image 18. The source data usually represents the primary colors red, green, and blue. The processor 30 processes the source data. The processor 30 has a color separation unit 33 coupled to the image scanner 40 for transforming and separating the primary color image data into data planes for each of the secondary colors cyan, magenta, and yellow. The processor also has a forensic identification unit 34

From the foregoing it will be appreciated that the printing systems and methods provided by the present invention represent a significant advance in the art. A printer can be constructed according to the present invention so as to provide a forensic marking system that unobtrusively marks printed media with encoded system information. The encoded system information can subsequently identify the system on which the media were printed with a high degree of accuracy, even where the markings are superimposed on other image content. Although several specific embodiments of the invention have been described and illustrated, the invention is not to be limited to the specific methods, forms, or arrangements of parts so described and illustrated. In particular, the invention may be used with single pass swath printers where a swath is fully printed during a single pass of the printheads 54 over the print medium 16, or with multipass swath printers where multiple passes of the printheads 54 over the print medium 16 are required to fully print a swath. It can be used with all types of swath printers including band printers and drum printers. It can be practiced with all types of inkjet printers including those which use thermal and piezo printing technologies; and with non-swath or non-inkjet color printers such as color laser printers. The invention is limited only by the claims.

3. The method of claim 2, wherein the at least one location marker (26a-b) is further indicative of the orientation of the forensic marking (20) on the print medium (16).

4. The method of claim 1, wherein the printing (S124) the output data further includes:

printing the source data using at least one of cyan, magenta, and yellow colorant; and

printing the at least one forensic marking (20) using yellow colorant.

5. The method of claim 1, further including:

rotating (S120) at least some of the individual ones of the at least one forensic marking (20) by a multiple of 90 degrees prior to the printing (S124).

6. The method of claim 1, further including:

adding (S118) to each of the at least one forensic markings (20) at least one camouflage marker (29) indicative of randomized data such that the visibility of the forensic markings (20) due to replication on the print medium (16) is reduced.

7. A system (10) for printing a forensically marked image, comprising:

a processor (30) for superimposing onto source data at least one forensic marking (20) so as to create output data corresponding to the forensically marked image (14), the at least one forensic marking (20) having

control means responsive to the detection means and coupled to the printer (50) for disabling the copying of the copy-prohibited subject matter.

10. A system (10) for determining a device on which a printed medium (17) was printed, comprising:

a media receptor (42) adapted to receive the printed medium (17);

an image scanner (40) in optical communication with the media receptor (42) for acquiring multicolor image data (18) for the printed medium (17);

a color separation unit (33) coupled to the image scanner (40) for segregating predetermined color image data from the multicolor image data (18); and

a forensic identification unit (34) coupled to the color separation unit (33) for identifying in the predetermined color image data at least one forensic marking (20) placed on the printed medium (17) by the device, the forensic identification unit (34) having

a locator subsystem (35) for locating an individual one of the at least one forensic marking (20) within the predetermined color image data,

a validation subsystem (37) for analyzing the individual forensic marking (20) so as to verify its integrity, and

an identification subsystem (36) for analyzing the individual forensic marking (20) so as to identify the device on which the printed medium (17) was printed.